Implementing Innovative Ideas in Structural Engineering and Project Management
*Edited by* Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

# LOAD BEARING STRUCTURAL ASSEMBLY

BRADFORD RUSSELL

*BR Architects & Engineers, Richardson, Texas, USA*

This article and research is based on recent patents filed with the USPTO (US Patent Serial No. 13/969,529 and 14/450,425), and Professional experiences in the built environment for over thirty years. The intention of this invention is focused on absorbing and / or redirecting forces two dimensionally or three dimensionally in any mechanism that relies on moving and / or force resolving components (structural manipulation of forces) so more benefits of the mechanism can be achieved under a longer duration.

*Keywords*: Frame, Force, Absorbing, Bending, Manipulation, Re-direction.

## 1 INTRODUCTION

One can assume when a member is being stressed in tension, compression, bending, or other, in pure form without the presence of the other, the member section is relying on the efficiency of the material, and / or the efficiency of the section. In particular, this is the case for a brace member in pure tension or pure compression. As the bending of members relies on both compression and tension, can a member's sections in bending be designed according to material and section properties for maximizing a member's performance? Could we expect better performance from a member section in tension, compression, bending, or other if it is held in a confined space? How can a force be resolved in a member under controlled deflection with the influence of eccentricity, i.e. beam / columns? Will / can a bracing system have a greater life expectancy when it is subject to a controlled limit of repetitive movement within the materials' property limits? The answer to some of these questions is obvious to the mechanically minded individual.

## 2 BENEFITS OF DEVICE

The Load Bearing Structural Assembly (Assembly) uses several techniques / structural fundamentals in creating an assembly for efficient force dissipation with, or without deflection / movement, causing a greater eccentricity, and with economy of material use: bending of a short column requires more force than one of greater length, stressing a member in a confined space requires more in-put force, placement / orientation of a member's section properties to maximize performance, efficient use of materials are arranged in section thus economizing costs, a member in bending can be configured to experience both compression and tension in the same member-section and thus take efficient advantage of the member material properties, a column with loading can be allowed within the kern to keep the allowable stresses within the allowable property limits of the materials, a member can be loaded in double curvature, and more, and increase the performance of the member section along the length, among other.

### 2.1 Explanation of Device

The Assembly includes an outer loop / arc member; an inner loop / arc member spaced apart from and sized smaller than the outer loop / arc member; a web assembly coupled to and extending between the outer loop / arc member and the inner loop / arc member, the web assembly comprising a plurality of arcuately formed web members. The properties of each outer and inner ring / arc, as well as web members can be set for a **controlled performance** – that of controlled directional movement, or lack thereof. In particular are the web member's properties for reaching these desired performances. This performance goes beyond the performance we consider in normal structural design and adds controlled directional movement among other in both 2D and 3D.

The Assembly is literally a flat spring which can be designed for a confined space and provide an array of outcomes / interact with an array of forces. The configurations of the Figures show the use of circles / arcs in more of a complete setting. However, the Assembly, in particular the web members, can be an arrangement of arcs to offer a desired response. And the inner and outer rings / arcs can be circular, or elliptical, or other as needed for any particular spatial need and response.

In review of Figure 1, one can see a possible configuration of the members, and recognize the efficiency of the circle / arc can be used to generate efficiency in strength, in particular in bending, but also in compression, tension, and shear. The allowable arrangement of the Assembly (Figure 1) within itself (web members within outer and inner rings / arcs), and as an assortment of Assemblies, can be limitless. In Figure 1 is shown an Assembly with six circular groups of web members. This arrangement, configuration of web members, numbering, width and flexibility, can be arranged for a predictable / controlled deflection in any direction, due to loading from any direction and type, thus creating a load bearing / a load dissipating assembly with greater efficiency, and advance the life of interacting parts. Specifically, the Assembly can control the deflection of the inner and outer rings / arcs in relation to each with a predictable, set limit of deflection with or without repetition of movement with the properties and arrangement of web members, and the properties and arrangement of inner and outer rings / arcs.

## 3 THE ASSEMBLAGE

The Assembly is set uniquely so that when it moves through angular deflection / rotation, the web members move into reverse curvature from the current position. This will have the effect of distributing the moment and shear through the member with respect to inflection points and will tend to limit the maximum values accordingly. This will cause the member section to act more efficiently through the length while reducing the moment and shears acting on the member section at any point.

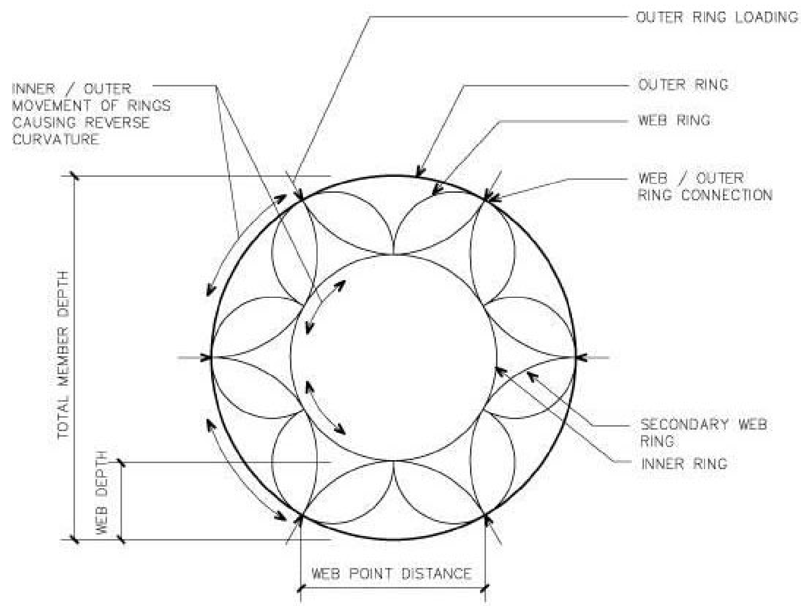


Figure 1. Load Bearing Structural Assembly: Component Section / Elevation – Schematic.

Figure 1 shows only a representation of possible assortments of the rings / arcs within the Assembly which will be set by the individual Assembly member's needed response, and member make-up and properties. The web members expected curvature are as shown in Figure 2, and as represented individually from Figure 1, are shown to go through an array of reverse curvatures as the Assembly is loaded. Shown are examples of single, double, and quadruple reverse curvatures which will have the tendency of reducing the moment / shear in the beam from that of single curvature by two and four respectively. With this, one can see the benefits more clearly for the uses of the Assembly in reducing the intended maximum moments and shears on the member sections.

It can be noted that the array of performances which can be achieved are limitless and will be derived from the actual performance needs of the Assembly. The typical stiffened mechanism uses stresses to dissipate forces to / through a member, but the Assembly uses stresses more evenly distributed through the member, as well as controlled movement in any direction to dissipate the forces. The Assembly can allow this controlled movement because of the circular / arc configuration moving through a series of additional curvatures and still not exceed its allowable eccentric displacement of the 'whole', allowing the member efficiency through the length. This has the tendency of making the member sections act more economically, extending the life of the Assembly, as well as other benefits for efficient member use.

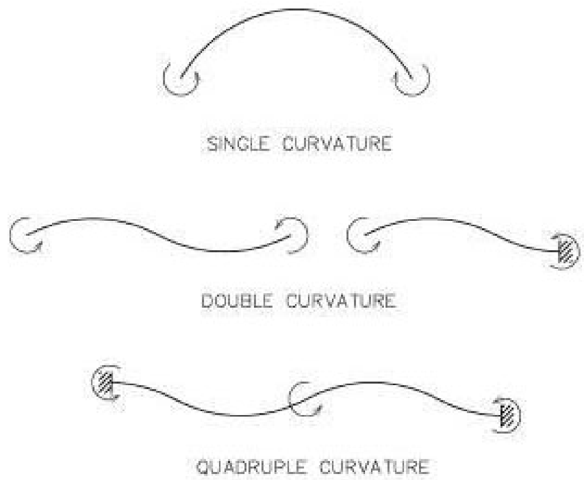


Figure 2. Curvature of Members.

## 4 ASSEMBLY EFFECTIVENESS

When reviewing how the Assembly achieves its effectiveness as a column, or beam, or beam / column, let us look at the basic equations of stress. One must understand from the beginning in a column, or beam it is very difficult to get pure axial loading, or pure bending. The maximum stresses can be found by evaluating the conditions that take into account the effects of bending and / or axial loading.

$$\sigma_{max} = P/A + Mc/I \quad (1)$$

$$P/P_d + 0.85M/M_p \leq 1.0 \quad (2)$$

$$M/M_p \leq 1.0 \quad (3)$$

In the Assembly, every member section has inherent properties (Area, Moment of Inertia, etc.) along its length and, when considered acting as an Assembly individually (Figure 1), or as an assortment of individual arc and circular members (Figure 2), the work can be allowed a greater loading due to any particular design arrangement of members and stay within the allowable stress limits. This arrangement can be broadened three dimensionally similar to a space truss, but arranged with the Assembly. With this, the actual stress on the member is due to a portion from axial loading and a portion from bending. Therefore, one can quickly see the control over the stresses by controlling a member length by bending through the inflection point, and thus the moment in the member. Additionally, each Assembly / member can use properties of the individual members as required to produce the response as needed.

The graph of Moment as it relates Axial Load in the determination of stress is generally considered linear in the elastic range. Input into the system as depicted in equation 1) above is set by P & M, the axial force and moment. Energy from that input is lost by movement of the system and heat of the individual members. Therefore, the stressing on the system is reduced by this loss.

### 4.1 Variables in Assembly

The variables which can be manipulated to provide the needed / desired response from the Assembly are first member properties including Moment of Inertia, Section Modulus, Area, Material Strengths, among other. But also, the web assembly configuration can be adapted to individual reaction needs, both direction and length of deflection, needed from the Assembly – Reference Figure 3. The web assembly configuration includes web depth, web member lengths, web member contact angle with inner and outer rings, quantity of web member arcs, shape of inner and outer rings, i.e. circular / elliptical, among other. This can allow a complete pallet of responses to meet a wide array of needs, as well as address repetition of response and extend working life of the mechanism being addressed with the Assembly.

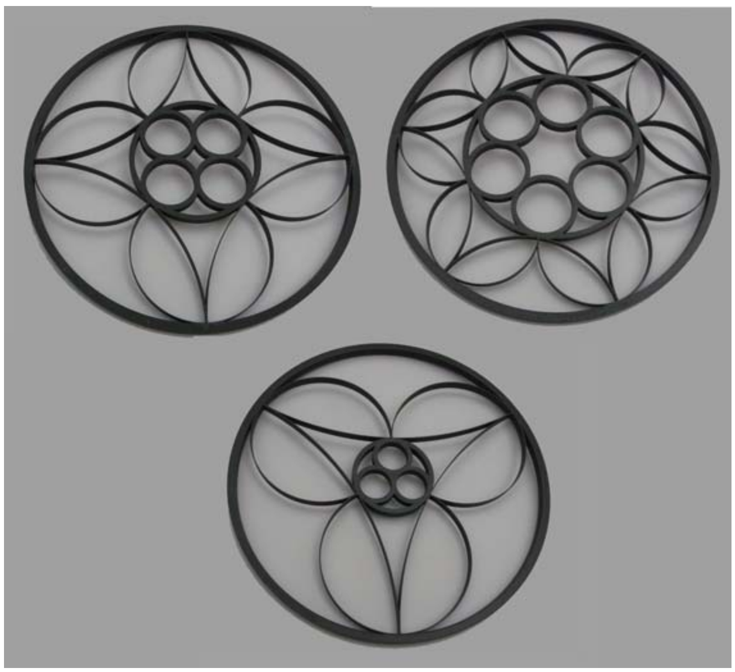

Figure 3. Various Web Assemblies.

The confinement of the web members will have the tendency to limit the act of stressing the members through bending. Intuitively, confining a member will tend to control the stress acting on the member section and hold the kern point within the member section perimeter. The arrangement / configuration of the web members will also tend to distribute the bending stresses more evenly through the Assembly. This will have a combined effect of preventing failure from over stress – bending and axial.

The primary structural parameters which are used in the Assembly are that of member curvature and confinement. If a member can be allowed / forced to move into double curvature instead of only single curvature, each length of the member can be allocated a portion of the moment in reverse, and the PΔ affect is minimized / controlled. This makes each member act more efficiently along the member length. The Assembly tends to force double curvature, by beam / column action of the web, while distributing forces by movement to the inner and outer ring / arc in relation to the other. This procedure is unique in that opposite members of the web are in tension / compression, similar to a beam in bending, but also in forcing single / double curvature in the web members along the length. This is distinctive to the Assembly and can be utilized in many mechanisms which rely on controlled movement / deflection, including a building's structural system.

## 5 CONCLUSION

This Assembly is not limited to use in a building frame system, but could also be used for an assortment of other directives from oil well head gaskets, to a car gears, to a door hinge springs, and many more with the performances magnified with controlled / directed rotations / deflections.

The research and modeling of this invention is showing the wide array of uses and the many benefits it can generate all mechanisms that rely on force distribution, re-distribution, and re-direction. When looking for resolutions of any current force issues, review Figure 1 for the Assembly's appropriateness in resolving the issue/s. This article is not intended to be exhaustive and touch on the full extents of use for the Assembly, but rather introduce the Assembly as a 'source'. We are sure you can look around where you currently sit and see a handful of other uses to increase the efficiency of a desired performance using these same principals.

Research on the assortment of applications and design optimization of this Assembly is on-going. The work will comprise the doctoral dissertation efforts of the author at Southern Methodist University.

## References

Bradford Russell Doctoral research, 'Framing Systems for Cyclical Loading Events', 2015, Southern Methodist University.

United States Patent and Trademark Office, 'Load Bearing Structural Assembly', Patent Appl. Serial No. 13/969,529, filed August 17, 2013.

United States Patent and Trademark Office, 'Load Bearing Structural Assembly', Patent Appl. Serial No. 14/450,425, filed August 4, 2014.